

## TITLE OF THE INVENTION

### IMAGE PROCESSING APPARATUS AND METHOD

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#### BACKGROUND OF THE INVENTION

The present invention relates to an image processing apparatus and method, and more particularly, to an image processing apparatus and method for performing color matching according to ambient light.

Fig. 1 is a conceptual view of general color matching.

Input RGB data is converted by an input profile to XYZ data of a color space which does not depend on any devices. Since an output device cannot express colors outside the color reproduction range of the output device, gamut mapping is performed on the inputted data, which has been converted to the data in the device-independent color space, such that all colors of the inputted data fall within the color reproduction range of the output device. After the gamut mapping is performed, the inputted data is converted from the device-independent color space to CMYK data of a color space which is dependent on the output device.

In color matching, a reference white point and

ambient light are fixed. For instance, according to a profile specified by the International Color Consortium (ICC), Profile Connection Space (PCS) for associating profiles uses XYZ values or Lab values based on D50 characteristic. Therefore, correct color reproduction is guaranteed when an inputted original document and a printout are viewed under an illuminant of D50 characteristic. Under an illuminant of other characteristics, correct color reproduction is not guaranteed.

When a sample (e.g., an image) is viewed under different illuminants, XYZ values of the viewed sample naturally vary. The XYZ values under various illuminants are predicted by conversion methods such as (1) ratio conversion, (2) Von Kries conversion, and (3) prediction formula using a color perception model.

In the ratio conversion method, XYZ values under a reference white point W1 are converted to XYZ values under a reference white point W2 at a ratio of W2/W1. If this conversion method is applied to the Lab uniform color space, the Lab values under W1 become equal to the Lab values under W2. Assuming that XYZ values of a sample under W1 ( $X_{w1}$ ,  $Y_{w1}$ ,  $Z_{w1}$ ) are ( $X_1$ ,  $Y_1$ ,  $Z_1$ ) and XYZ values of the sample under W2 ( $X_{w2}$ ,  $Y_{w2}$ ,  $Z_{w2}$ ) are ( $X_2$ ,  $Y_2$ ,  $Z_2$ ), the following relations are obtained by the ratio conversion:

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$$\left. \begin{aligned} X2 &= \frac{Xw2}{Xw1} X1 \\ Y2 &= \frac{Yw2}{Yw1} Y1 \\ Z2 &= \frac{Zw2}{Zw1} Z1 \end{aligned} \right\} \dots (1)$$

According to the Von Kries conversion, XYZ values under the reference white point W1 are converted to XYZ values under the reference white point W2 at a ratio of W2'/W1' in a human color perception space PQR. If this conversion method is applied to the Lab uniform color space, the Lab values under W1 do not become equal to the Lab values under W2. Assuming that XYZ values of a sample under W1 (Xw1, Yw1, Zw1) are (X1, Y1, Z1) and XYZ values of the sample under W2 (Xw2, Yw2, Zw2) are (X2, Y2, Z2), the following relations are obtained by Von Kries conversion:

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$$\begin{bmatrix} X2 \\ Y2 \\ Z2 \end{bmatrix} = \begin{bmatrix} inv\_Mat \\ 0 \\ 0 \end{bmatrix} \begin{bmatrix} Pw2/Pw1 & 0 & 0 \\ 0 & Qw2/Qw1 & 0 \\ 0 & 0 & Rw2/Rw1 \end{bmatrix} \begin{bmatrix} Mat \\ Y1 \\ Z1 \end{bmatrix} \dots (2)$$

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where

$$\begin{bmatrix} Pw2 \\ Qw2 \\ Rw2 \end{bmatrix} = \begin{bmatrix} Mat \\ \end{bmatrix} \begin{bmatrix} Xw2 \\ Yw2 \\ Zw2 \end{bmatrix} \quad \dots(3)$$

$$\begin{bmatrix} Pw1 \\ Qw1 \\ Rw1 \end{bmatrix} = \begin{bmatrix} Mat \\ \end{bmatrix} \begin{bmatrix} Xw1 \\ Yw1 \\ Zw1 \end{bmatrix} \quad \dots(4)$$

$$5 \quad \begin{bmatrix} inv\_Mat \\ \end{bmatrix} = \begin{bmatrix} 1.85995 & -1.12939 & 0.21990 \\ 0.36119 & 0.63881 & 0 \\ 0 & 0 & 1.08906 \end{bmatrix} \quad \dots(5)$$

$$\begin{bmatrix} Mat \\ \end{bmatrix} = \begin{bmatrix} 0.44024 & 0.70760 & -0.08081 \\ -0.22630 & 1.16532 & 0.04570 \\ 0 & 0 & 0.91822 \end{bmatrix} \quad \dots(6)$$

To convert XYZ values under a viewing condition  
 10 VC1 (including W1) to XYZ values under a viewing  
 condition VC2 (including W2), the prediction formula  
 using a color perception model, which is a conversion  
 method such as CIE CAM 97s using the human color  
 perception space QMH (or JCH) is employed. Herein, Q  
 15 for QMH represents brightness, M represents  
 colorfulness, and H represents hue quadrature or hue  
 angle. J for JCH represents lightness, C represents  
 chroma, and H represents hue quadrature or hue angle.  
 If this conversion method is applied to the Lab uniform  
 20 color space, the Lab values under W1 are not equal to

the Lab values under W2, as similar to the case of the Von Kries conversion. Assuming that XYZ values of a sample under W1(Xw1, Yw1 Zw1) are (X1, Y1, Z1) and XYZ values of the sample under W2(Xw2, Yw2, Zw2) are (X2, Y2, Z2), the Von Kries conversion performs the following conversion:

(X1, Y1, Z1) → [forward conversion of CIE CAM97s] → (Q, M, H) or (J, C, H) → [inverse conversion of CIE CAM97s] (X2, Y2, Z2)

In other words, if it is assumed that XYZ values under a reference white point which varies depending on a ratio conversion can be converted, the contour lines of hue in the Lab color spaces under various reference white points are always the same. However, if human color perception is taken into consideration, such as the Von Kries conversion or prediction formula using a color perception model, the contour lines of hue in the Lab color spaces under different reference white points vary depending on the reference white points.

Because of the above reason, if gamut mapping (hue restoration) defined under one Lab color space is applied to color matching under different reference white points, the human vision perceives the hue as inconsistent.

Moreover, in the current ICC profile, since the PCS is limited to XYZ values or Lab values based on D50 characteristic, color matching corresponding to ambient light cannot be performed.

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#### SUMMARY OF THE INVENTION

The present invention is made in consideration of the above situation, and has as its object to provide  
10 an image processing apparatus and method for performing excellent color matching under different viewing conditions.

In order to attain the above object, the present invention provides an image processing method for  
15 performing color process based on a color appearance model, the image processing method comprising the steps of: inputting location information which relates to a positional relation between a viewing subject in a data source side and a viewing subject in a data destination  
20 side; and controlling the color process based on the inputted location information.

Another object of the present invention is to provide an image processing apparatus and method for enabling a user to readily set a viewing condition.

25 In order to attain the above object, the present invention provides an image processing method having a

user interface for manually inputting location  
information which relates to a positional relation  
between a viewing subject in a data source side and a  
viewing subject in a data destination side, and a user  
5 interface for manually inputting viewing information  
which relates to a viewing condition, for performing  
color process on input image data based on a color  
appearance model, the image processing method  
comprising the step of controlling the color process  
10 based on the inputted location information and viewing  
information.

Other features and advantages of the present  
invention will be apparent from the following  
description taken in conjunction with the accompanying  
15 drawings, in which like reference characters designate  
the same or similar parts throughout the figures  
thereof.

#### BRIEF DESCRIPTION OF THE DRAWINGS

20 The accompanying drawings, which are incorporated  
in and constitute a part of the specification,  
illustrate embodiments of the invention, and together  
with the description, serve to explain the principles  
25 of the invention.

Fig. 1 is a conceptual view of color matching;

Fig. 2 is an explanatory view showing a concept of the present invention;

Fig. 3 is a block diagram showing the functional configuration of a first embodiment of the present invention;

Fig. 4 is a flowchart showing the process of reconstructing a conversion LUT which corresponds to an ambient light;

Fig. 5 is a flowchart showing the process of updating a conversion LUT so as to correspond to an ambient light;

Fig. 6 is a flowchart showing the process of performing gamut mapping in the color space JCH or QMH;

Fig. 7 shows a dodecahedron for approximating a color reproduction range;

Figs. 8A and 8B are conceptual views of gamut mapping in the JCH color perception space;

Figs. 9A and 9B are conceptual views of gamut mapping in the QMH color perception space;

Figs. 10A and 10B are conceptual views of gamut mapping performed between different devices;

Fig. 11 is a flowchart showing the process of reconstructing a conversion LUT which corresponds to an ambient light;

Fig. 12 is a conceptual view of color matching processing;



Fig. 13 is a conceptual view of color matching according to a second embodiment of the present invention;

Fig. 14 is a flowchart showing the process of performing gamut mapping in the color space JCH or QMH according to the second embodiment;

Fig. 15 is a flowchart showing the process of reconstructing a conversion LUT which corresponds to an ambient light according to the second embodiment;

Fig. 16 is a conceptual view of color matching according to a third embodiment of the present invention;

Fig. 17 is a flowchart showing the process of updating a conversion LUT so as to correspond to an ambient light in the second embodiment;

Fig. 18 is a block diagram showing a construction of an apparatus which realizes the functional configuration shown in Fig. 3;

Fig. 19 is an explanatory block diagram of a color appearance model used in the embodiments of the present invention;

Fig. 20 is a conceptual view of a profile storing XYZ values of a white point under different illuminants, device-dependent RGB values of a color target, XYZ values corresponding to the color target under respective illuminants;

Fig. 21 shows a spectral distribution of a standard illuminant;

Fig. 22 is a flowchart showing the process of conjecturing a colorimetric value from the colorimetric data for plural illuminants;

Fig. 23 shows an example in which a LUT, provided for mutually converting a device-independent color space under a viewing condition to a device-dependent color space, is stored in the ICC profile;

Fig. 24 is a flowchart showing caching processing;

Fig. 25 shows an example of a Graphic User Interface (GUI) for setting a parameter of a viewing condition according to a sixth embodiment of the present invention;

Fig. 26 shows an example of a GUI which enables setting of a user level; and

Fig. 27 shows the GUI of Fig. 26, whose user level is set in "professional level".

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the image processing apparatus and method as well as the profile generating method according to the present invention will be described in detail with reference to the accompanying

drawings.

First, a color appearance model used in the following embodiments is described with reference to Fig. 19.

- 5           A color perceived by human visual system is different depending on conditions, such as the difference in lighting or a background on which a stimulus as a viewing subject is placed, even if the characteristic of light entering the eye is the same.
- 10           For instance, a white color, illuminated by an incandescent lamp, is not perceived as red as the characteristic of light entering the eye, but is perceived as white. A white color placed on a black background is perceived brighter than a white color
- 15           placed on a bright background. The former phenomenon is known as chromatic adaptation and the latter is known as a contrast. In view of this, colors must be displayed not by the XYZ color system, but by the volume corresponding to a physiological activity level
- 20           of visual cells distributed on the retina. For this purpose, a color appearance model has been developed. The CIE (Commission Internationale de l'Eclairage) recommends using the CIE CAM97s. This color appearance model utilizes color perception correlation values,
- 25           which are H (hue), J (lightness) and C (chroma), or H (hue), Q (brightness) and M (colorfulness), as

physiological three primary colors of color vision, and is considered as a color display method which do not depend upon viewing conditions. By reproducing colors so as to match the values of H, J and C or H, Q and M  
5 between devices, it is possible to solve the problem of different viewing conditions in an input image and output image.

Description will be provided with reference to Fig. 19 for the processing of forward conversion of the  
10 color appearance model CIE CAM97s, for performing correction processing (conversion from XYZ to JCH or QMH) in accordance with a viewing condition at the time of viewing an image to be inputted.

In step S160, LA indicative of a luminance of an  
15 adaptive visual field ( $\text{cd/m}^2$ ) (normally, 20% of white luminance in the adaptive visual field is selected), XYZ indicative of relative tristimulus values of a sample under an illuminant condition,  $X_wY_wZ_w$  indicative of relative tristimulus values of a white light under  
20 the illuminant condition, and  $Y_b$  indicative of a relative luminance of a background under the illuminant condition are set as the viewing condition information of an image to be inputted. Based on the type of viewing condition specified in step S180, a constant  $c$   
25 indicative of an impact of surround, a chromatic induction factor  $N_c$ , a lightness contrast factor  $FLL$ ,

and an factor for degree of adaptation  $F$  are set as the viewing condition information of the input image in step S170.

Based on the input image viewing condition  
5 information set in steps S160 and S170, the following processing is performed on the XYZ representing an input image.

First, the XYZ are converted based on the  
Bradford's three primary colors, which are considered  
10 as human physiological three primary colors, to obtain RGB corresponding to Bradford's cone response (step S100). Since human vision does not always completely adapt to the viewing illuminant, a variable  $D$  indicative of adaptability is obtained based on a  
15 luminance level and a viewing condition ( $LA$  and  $F$ ). Based on the obtained variable  $D$  and  $XwYwZw$ , incomplete adaptation processing is performed on RGB to be converted to  $RcGcBc$  (step S110).

Next,  $RcGcBc$  is converted based on Hunt-Pointer-  
20 Estevez's three primary colors, which are considered as human physiological three primary colors, to obtain  $R'G'B'$  corresponding to Hunt-Pointer-Estevez's cone response (step S120). The adaptability of  $R'G'B'$  is estimated by a stimulus intensity level to obtain  
25  $R'aG'aB'a$  corresponding to an adapted cone response which corresponds to both the sample and white (step

S130). Note that in step S130, non-linear response compression is performed by using a variable FL which is calculated based on the luminance LA of the adaptive visual field.

- 5           Then, to obtain the correlation between a color perception and the XYZ, the following processing is performed.

          Opposite color responses a and b of red-green and yellow-blue are calculated from  $R'aG'aB'a$  (step S140),  
10   and a hue H is calculated from the opposite color responses a and b and a eccentricity factor (step S150).

          Then, a background inducing coefficient n is calculated from Yw and the relative luminance Yb of the background. By using the background inducing  
15   coefficient n, achromatic color responses A and Aw with respect to both the sample and white are calculated (step S190). Lightness J is calculated by using a coefficient z, calculated from the background inducing coefficient n and lightness contrast factor FLL, and  
20   the achromatic color responses A and Aw as well as the impact of surround constant c (step S151). A saturation S is calculated from the chromatic induction factor NL (step S153), then from the saturation S and lightness J, a chroma C is calculated (step S152), and  
25   a brightness Q is calculated from the lightness J and achromatic color response Aw for white (step S154).

A colorfulness M is calculated from the variable FL and impact of surround constant c (step S155).

<First Embodiment>

- 5 Description is provided for the first embodiment in which a profile is dynamically changed in accordance with a viewing condition.

Referring to Fig. 2 which describes a concept of the present invention, reference numeral 11 denotes a  
10 conversion matrix or a conversion lookup table (LUT) for converting data which is dependent on an input device (hereinafter referred to as input-device-dependent data) to data of the device-independent color space (hereinafter referred to as input-independent  
15 data), which accords to a white point of ambient light at the time of viewing an image formed on an original. Reference numeral 12 denotes a forward converter (CAM) of a color appearance model for converting data, obtained from the conversion LUT 11, to human color  
20 perception color space JCh or QMh. Reference numeral 13 denotes a relative color perception space JCh (or JCH) relative to the reference white of an ambient light; and 14, an absolute color perception space QMh (or QMH) whose size changes in accordance with an  
25 illuminance level. Reference numeral 15 denotes an inverse converter of a color appearance model for

converting data of the human's color perception space  
JCh or QMh to data of the device independent color  
space (hereinafter referred to as output-independent  
data), which accords to a white point of ambient light  
5 at the time of viewing an image formed on a printout.  
Reference numeral 16 denotes a conversion LUT for  
converting data, obtained from the inverse converter 15,  
to data which is dependent on an output device  
(hereinafter referred to as output-device-dependent  
10 data).

Generally, the white point of ambient light under  
a viewing condition is different from a white point of  
the standard illuminant at the time of colorimetry of a  
color target or color patch or the like. For instance,  
15 the standard illuminant used at the time of colorimetry  
is D50 or D65, but an ambient light for actually  
viewing an image is not always D50 or D65 in a light  
booth. An illumination light from an incandescent lamp  
or fluorescent light, or a combination of illumination  
20 light and sunlight are often used as the ambient light  
in which the image is actually viewed. In the  
following description, although an illuminant  
characteristic of an ambient light under a viewing  
condition is assumed as D50, D65 and D93 to simplify  
25 the description, in reality, XYZ values of a white  
point on a medium is set as a white point.



Fig. 3 is a block diagram showing a functional configuration of the present embodiment. In Fig. 3, reference numeral 41 denotes a data generation portion for generating data, which is dependent on the viewing condition 1 of a data input side, based on an input profile 42 and the viewing condition 1. Reference numeral 43 denotes a gamut mapping mode selection portion for selecting whether the gamut mapping is performed in the JCH color perception space or in the QMH color perception space in accordance with designation by a user or designation by the profile. Reference numerals 44 and 45 denote gamut mapping portions respectively for performing gamut mapping on data in the JCH or QMH color perception space in accordance with an output profile 46. Reference numeral 47 denotes a data generation portion for generating data, which is dependent on a viewing condition 2 of an image output side, based on the output profile 46 and viewing condition 2. Reference numeral 48 denotes a color matching portion for performing color matching by utilizing the data which is dependent on the viewing condition 1, the gamut mapped data, the data which is dependent on the viewing condition 2, and color appearance model.

Fig. 18 is a block diagram showing a construction of an apparatus which realizes the functional

configuration shown in Fig. 3. It goes without saying  
that the apparatus shown in Fig. 18 is realized by  
supplying a general computer apparatus, such as a  
personal computer or the like, with software which  
5 realizes the function shown in Fig. 3. In this case,  
the software which realizes the function of the present  
embodiment may be included in the Operating System (OS)  
which is the basic system software of the computer  
apparatus, or may be provided, for instance, as a  
10 driver software of an input/output device independently  
of the OS.

In Fig. 18, a CPU 100 controls operation of the  
entire apparatus according to a program stored in a ROM  
101 and hard disk (HD) 106 and the like, by utilizing a  
15 RAM 102 as a work memory, and executes various  
processing including the processing related to the  
above-described color matching. An input interface 103  
is provided to connect an input device 104; a hard disk  
interface 105 is provided to connect the HD 106; a  
20 video interface 107 is provided to connect a monitor  
108; and an output interface 109 is provided to connect  
an output device 110.

Note that the input device according to the  
present embodiment includes an image sensing device  
25 such as a digital still camera or a digital video  
camera or the like, and various image input devices

including an image reader such as an image scanner or film scanner or the like. The output device according to the present embodiment includes a color monitor such as a CRT or LCD or the like, and an image output device  
5 such as a color printer or film recorder or the like.

A general interface is utilized as the interface of the present embodiment. Depending on the usage purpose, a serial interface such as RS232C, RS422 or the like, a serial bus interface such as IEEE 1394,  
10 Universal Serial Bus (USB) or the like, and a parallel interface such as SCSI, GPIB, centronics or the like, are applicable.

Input/output profiles for color matching are stored in the HD 106. However, the storage medium is  
15 not limited to hard disk, but may be an optical disk such as a magneto-optical disk (MO) or the like.

Hereinafter, description is provided for an example of performing color matching by using the input/output profiles.

20

[Generating Data Dependent on Viewing Condition 1]

The conversion LUT 11 is generated by the data generation portion 41. Methods of generating the conversion LUT 11 include: a method of reconstructing  
25 the conversion LUT 11 so as to correspond to an ambient light, based on a relation between XYZ values (or Lab

values) of a color target and RGB values of an input device as shown in Fig. 4; and a method of updating a conversion LUT stored in the input profile 42, which is provided for converting an RGB space dependent on a  
5 device to XYZ color space, to the conversion LUT 11 which corresponds to the ambient light.

Fig. 4 is a flowchart showing the process of reconstructing the conversion LUT 11 which corresponds to an ambient light.

10 To reconstruct the conversion LUT 11 so as to correspond to an ambient light, a profile designated by a user is read from the input profile 42 in step S51. XYZ values (or Lab values) of the color target and XYZ-to-  
15 to-RGB relation data, which associates the XYZ values with RGB values for a case of reading the color target by an input device, are stored in advance in the profile. The XYZ-to-  
20 to-RGB relation data is obtained from the profile in step S52. Since the profile includes a viewing condition 1, the viewing condition 1 is obtained from the profile in step S53.

The XYZ values of the XYZ-to-  
to-RGB relation data, obtained in step S52, employ as a reference, D50 or D65 indicative of a reference light at the time of  
colorimetry of the color target. Therefore, the XYZ  
25 values of the colorimetric illuminant reference must be corrected to XYZ values of an ambient light reference.

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In step S54, by using the color appearance model, the XYZ values of the colorimetric illuminant reference are converted to the color perception space JCH based on a colorimetric condition, i.e., the white point of D50 illuminant, an illuminance level, and the state of ambient light, and then the converted values in the color perception space JCH are converted back to XYZ values based on the viewing condition 1 different from the colorimetric condition, e.g., the white point of D65 illuminant, an illuminance level, and the state of ambient light. By this, XYZ values of the ambient light reference are obtained. In the foregoing manner, the relation between XYZ values of the ambient light reference and device RGB values is obtained. In step S55, an RGB-to-XYZ conversion matrix is generated based on the RGB-to-XYZ relation data and optimized by repetition or the like, thereby obtaining the conversion LUT 11 which corresponds to the viewing condition 1.

Fig. 5 is a flowchart showing the process of updating the conversion LUT, stored in the input profile 42, to the conversion LUT 11 which corresponds to an ambient light. Note that the steps in Fig. 5 executing the same processing as those in Fig. 4 have the same reference step number, and detailed description thereof is omitted.

Generally in the ICC profile for an input device,  
a conversion matrix (colorant Tag) for performing RGB-  
to-XYZ conversion, or a conversion LUT (AtoB0 Tag) is  
stored. Thus, the RGB-to-XYZ relation data is obtained  
5 from the profile in step S62.

In step S54, the relation between XYZ values of  
the ambient light reference and device RGB values is  
obtained. Then in step S66, the conversion matrix  
(colorant Tag) or conversion LUT (AtoB0 Tag) in the  
10 profile is updated. As a result, a conversion LUT,  
updated to the conversion LUT 11 corresponding to the  
viewing condition 1, is obtained.

Moreover, although Figs. 4 and 5 provide an  
example of utilizing the RGB-to-XYZ relation data, the  
15 present invention is not limited to this, but may  
utilize other device-independent color data such as  
RGB-to-Lab relation data.

[Selecting Gamut Mapping Mode and Performing Gamut  
20 Mapping]

A gamut mapping mode is selected by a user  
through a user interface, or automatically selected by  
Rendering Intent included in the header of a source  
profile. The following selection is made in the  
25 automatic selection according to the profile.

Perceptual -- gamut mapping mode in JCH color space

Relative Colorimetric -- gamut mapping mode in JCH color space

5 Saturation -- gamut mapping mode in JCH color space

Absolute Colorimetric -- gamut mapping mode in QMH color space

10 In other words, in a case of relative color matching, JCH space 13 is selected, while in a case of absolute color matching, QMH space 14 is selected.

Fig. 6 is a flowchart showing the process of performing the gamut mapping in the color perception space JCH 13 or color perception space QMH 14.

In order to perform the gamut mapping in a color perception space, a profile designated by a user is read from the output profile 46 in step S81.

Generally in the ICC profile for an output device, a judgment LUT (gamut Tag), to which XYZ values or Lab values are inputted, is stored in order to judge inside or outside the color reproduction range (hereinafter referred to as inside/outside judgment of the color reproduction range). However, because the XYZ values employ D50 or D65 which is the characteristic of colorimetric illuminant as a reference, the XYZ values

cannot be used directly to make judgment of  
inside/outside the color reproduction range according  
to an ambient light. Therefore, instead of using the  
judgment LUT (gamut Tag) which judges inside/outside  
5 the color reproduction range, CMYK-to-XYZ relation data  
is obtained in step S82 from the conversion LUT (AtoB0  
Tag or the like), stored in the profile for CMYK-to-XYZ  
conversion. Since the profile includes the viewing  
condition 2, the viewing condition 2 is obtained from  
10 the profile in step S83.

The XYZ values of the CMYK-to-XYZ relation data,  
obtained in step S82, employ as a reference, D50 or D65  
indicative of a colorimetric light. Therefore, the XYZ  
values of the colorimetric illuminant reference must be  
15 corrected to XYZ values of an ambient light reference.  
In step S84, by using the color appearance model, the  
XYZ values of the colorimetric illuminant reference are  
converted to the color perception space JCH based on a  
colorimetric condition, i.e., the white point of D50  
20 illuminant, an illuminance level, and the state of  
ambient light, and then the converted values in the  
color perception space JCH are converted back to XYZ  
values based on the viewing condition 2 different from  
the colorimetric condition, e.g., the white point of  
25 D65 illuminant, an illuminance level, and the state of  
ambient light. By this, XYZ values of the ambient



light reference are obtained. In the foregoing manner, the relation between the device CMYK values and XYZ values of the ambient light reference is obtained in step S84. In step S85, a color reproduction range of an output device in the JCH or QMH color space is obtained based on the CMYK-to-ambient-light-XYZ relation data obtained in step S84.

The color reproduction range of an output device in the JCH or QMH color space is obtained as follows. XYZ values of an ambient light reference on the following eight points, shown as an example, are obtained by using the CMYK-to-ambient-light-XYZ relation data obtained in step S84.

15	Red	(C:0%, M:100%, Y:100%, K:0%)
	Yellow	(C:0%, M:0%, Y:100%, K:0%)
	Green	(C:100%, M:0%, Y:100%, K:0%)
	Cyan	(C:100%, M:0%, Y:0%, K:0%)
	Blue	(C:100%, M:100%, Y:0%, K:0%)
20	Magenta	(C:0%, M:100%, Y:0%, K:0%)
	White	(C:0%, M:0%, Y:0%, K:0%)
	Black	(C:0%, M:0%, Y:0%, K:100%)

Then, the obtained XYZ values are converted to coordinate values in the color perception space JCH or QMH based on the viewing condition 2 by using the color

appearance model. By this, the color reproduction range of the output device can be approximated by a dodecahedron shown in Fig. 7.

In the color reproduction range approximated by the dodecahedron, for instance, if an intermediate point between White and Black on an achromatic color axis and a point represented by JCH values or QMH values of an input color signal subjected to inside/outside judgment exist in the same side, it is judged that the input color signal is inside the color reproduction range, while if these points exist in the opposite sides, it is judged that the input color signal is outside the color reproduction range.

Based on the result of inside/outside judgment of the color reproduction range in step S85, the gamut mapping is performed in step S86. Figs. 8A and 8B are conceptual views of the gamut mapping in the JCH color perception space. Figs. 9A and 9B are conceptual views of the gamut mapping in the QMH color perception space. If an input color signal is judged as being outside the color reproduction range of the output device in the aforementioned inside/outside judgment, the input color signal is mapped in the color reproduction range such that a hue angle  $h$  (or  $H$ ) is preserved in the JCH color perception space or QMH color perception space. The mapping result is stored in the LUT for the JCH color

perception space in a case of relative color matching,  
or stored in the LUT for the QMH color perception space  
in a case of absolute color matching.

Figs. 10A and 10B are conceptual views of the  
5 gamut mapping performed between different devices. In  
the drawings, the broken lines indicate a color  
reproduction range of an input device, and the solid  
lines indicate a color reproduction range of an output  
device. In the JCH color perception space, the level  
10 of J (lightness) is normalized respectively by  
illuminant white points under the viewing conditions 1  
and 2 (hereinafter referred to as "white point 1" and  
"white point 2"). Thus, J does not depend on the  
illuminance levels of the viewing conditions 1 and 2  
15 (hereinafter referred to as "illuminance level 1" and  
"illuminance level 2"). On the other hand, in the QMH  
color perception space, the level of Q (brightness)  
changes in accordance with the illuminance levels 1 and  
2. Therefore, in the relative color matching, the  
20 white point 1 becomes the white point 2. Meanwhile in  
the absolute color matching, if illuminance level 1 >  
illuminance level 2, the white point 1 is mapped to the  
white point 2. If illuminance level 1 < illuminance  
level 2, the white point 1 is outputted in gray color  
25 because the white point 1 is lower than white point 2.

[Generating Data Dependent on Viewing Condition 2]

Next, the conversion LUT 16 is generated by the data generation portion 47.

Fig. 11 is a flowchart showing the process of reconstructing the conversion LUT 16 which corresponds to an ambient light.

Generally in the ICC profile for an output device, a LUT (BtoA0 Tag or the like) for converting XYZ or Lab values to device CMYK or RGB values is stored in the form including information of the gamut mapping. However, since the XYZ values inputted to the LUT employ D50 or D65 as a reference, the XYZ values cannot be directly used as a conversion LUT which corresponds to an ambient light.

As similar to the gamut mapping processing, a conversion LUT (AtoB0 Tag or the like) for performing CMYK-to-XYZ conversion is read from the output profile 46 in step S71, and CMYK-to-XYZ relation data is obtained from the conversion LUT in step S72. Note that CMYK values of the CMYK-to-XYZ relation data may be other device-dependent colors such as RGB values or the like, and XYZ values may be other device-independent colors such as Lab values or the like. In step S73, the viewing condition 2 is obtained from the output profile 46 which stores the viewing condition 2 in advance.

The XYZ values of the obtained CMYK-to-XYZ relation data employ D50 or D65 as a reference. Therefore, the XYZ values of the colorimetric illuminant reference must be corrected to XYZ values of an ambient light reference in step S74. More specifically, by using the color appearance model, the XYZ values of the colorimetric illuminant reference are converted to the color perception space JCH based on a colorimetric condition, i.e., the white point of D50 illuminant, an illuminance level, and the state of ambient light, and then the converted values in the color perception space JCH are converted back to XYZ values based on the viewing condition 2 different from the colorimetric condition, e.g., the white point of D65 illuminant, an illuminance level, and the state of ambient light. By this, XYZ values of the ambient light reference are obtained. In the foregoing manner, the relation between the device CMYK values and XYZ values of the ambient light reference is obtained. In step S75, ambient light XYZ-to-CMYK relation data is optimized by repetition or the like, using the CMYK-to-ambient-light-XYZ relation data, thereby obtaining the conversion LUT 16 which corresponds to a desired ambient light.

25

[Executing Color Matching]

Fig. 12 is a conceptual view of color matching processing. Reference numeral 11 denotes a conversion LUT generated based on the viewing condition 1 by the data generation portion 41; 132, a LUT generated in the JCH color space by the gamut mapping portion 44; 133, a LUT generated in QMH color space by the gamut mapping portion 45; and 16, a conversion LUT generated based on the viewing condition 2 by the data generation portion 47.

10 RGB or CMYK input color signals are converted by the conversion LUT 11 from the input-device-dependent color signals to XYZ signals which are device-independent signals under the viewing condition 1. Next, the XYZ signals are converted by color appearance model forward converters 134 and 135 to perception signals JCH or QMH, based on the viewing condition 1, such as the white point of D50 illuminant, an illuminance level, and the state of ambient light. In a case of relative color matching, JCH space is selected, while in a case of absolute color matching, QMH space is selected.

The color perception signals JCH and QMH are mapped to a color reproduction range of the output device by the LUT 132 and 133. The color perception signals JCH and QMH, where the gamut mapping has been performed, are converted by color appearance model

inverse converters 136 and 137 to XYZ signals which are device-independent signals under the viewing condition 2, based on the viewing condition 2, such as the white point of D65 illuminant, an illuminance level, and the state of ambient light. Then, XYZ signals are converted to output-device-dependent color signals under the viewing condition 2 by the conversion LUT 134.

The RGB or CMYK signals obtained by the above processing are sent to the output device, and an image represented by the color signals is printed. When the printout is viewed under the viewing condition 2, the colors of the printout are perceived as the same as the original document viewed under the viewing condition 1.

#### <Second Embodiment>

Hereinafter, described as a second embodiment is an example of color matching utilizing an input profile and monitor profile shown in Fig. 13. Note that the construction and processing similar to that of the first embodiment will not be described in detail.

[Generating Data Dependent on Viewing Condition 1]

A conversion LUT 21 shown in Fig. 13 is generated by the data generation portion 41 in the same method as described in the first embodiment, i.e., the processing shown in Figs. 4 and 5.

[Selecting Gamut Mapping Mode and Performing Gamut Mapping]

Since the selection of a gamut mapping mode is  
5 performed in the same manner as that of the first  
embodiment, detailed description will not be provided.

Fig. 14 is a flowchart showing the process of  
performing the gamut mapping in the color perception  
space JCH 23 or color perception space QMH 24 shown in  
10 Fig. 13.

To perform the gamut mapping in a color  
perception space, a profile designated by a user is  
read from a monitor profile 142 in step S141.

Generally in the ICC profile for a monitor device,  
15 a judgment LUT (gamut Tag), to which XYZ values or Lab  
values are inputted, is often stored in order to make  
inside/outside judgement of the color reproduction  
range. However, because the XYZ values employ D50 or  
D65 which is the characteristic of colorimetric  
20 illuminant as a reference, the XYZ values cannot be  
used directly to make judgment of inside/outside the  
color reproduction range according to an ambient light.  
Therefore, instead of using the judgment LUT (gamut  
Tag) which judges inside/outside the color reproduction  
25 range, RGB-to-XYZ relation data is obtained in step  
S142 from a conversion matrix (colorant Tag) or



conversion LUT (AtoB0 Tag or the like), stored in the profile for RGB-to-XYZ conversion. Since the monitor profile includes a monitor viewing condition 4, the viewing condition 4 is obtained from the monitor

5 profile in step S143. Note that XYZ values of the RGB-to-XYZ relation data may be other device-independent color values such as Lab values.

The XYZ values of the RGB-to-XYZ relation data, obtained in step S142, employ D50 indicative of a  
10 colorimetric light, or a monitor's white point as a reference. Therefore, the XYZ values of the colorimetric illuminant reference must be corrected to XYZ values of an ambient light reference. In step S144, by using the color appearance model, the XYZ values of  
15 the colorimetric illuminant reference are converted to the color perception space JCH based on a colorimetric condition, i.e., the white point of D50 illuminant, a luminance level, and the state of ambient light, and then the converted values in the color perception space  
20 JCH are converted back to XYZ values based on the viewing condition 4 different from the colorimetric condition, e.g., the white point of D93 illuminant, a luminance level, and the state of ambient light. By this, XYZ values of the ambient light reference are  
25 obtained. In the foregoing manner, the relation between the device RGB values and XYZ values of the

ambient light reference is obtained. In step S145, a color reproduction range of a monitor device in the JCH or QMH color space is obtained.

The color reproduction range of a monitor device  
5 is obtained as follows. XYZ values of an ambient light reference on the following eight points, shown as an example, are obtained by the conversion processing of XYZ reference condition in step S144.

	Red	(R:255, G:0, B:0)
10	Yellow	(R:255, G:255, B:0)
	Green	(R:0, G:255, B:0)
	Cyan	(R:0, G:255, B:255)
	Blue	(R:0, G:0, B:255)
	Magenta	(R:255, G:0, B:255)
15	White	(R:255, G:255, B:255)
	Black	(R:0, G:0, B:0)

Then, the obtained XYZ values are converted to coordinate values in the color perception space JCH or  
20 QMH based on the viewing condition 4 by using the color appearance model. By this, the color reproduction range of the monitor device can be approximated by a dodecahedron shown in Fig. 7. In the color reproduction range approximated by the dodecahedron,  
25 for instance, if an intermediate point between White and Black on an achromatic color axis and a point

represented by JCH values or QMH values of an input color signal subjected to inside/outside judgment exist in the same side, it is judged that the input color signal is inside the color reproduction range, while if  
5 these points exist in the opposite sides, it is judged that the input color signal is outside the color reproduction range.

Based on the result of inside/outside judgment of the color reproduction range in step S145, the gamut mapping is performed in step S146. Figs. 8A and 8B are conceptual views of the gamut mapping in the JCH color perception space. Figs. 9A and 9B are conceptual views of the gamut mapping in the QMH color perception space. If an input color signal is judged as being outside the  
15 color reproduction range of the output device in the aforementioned inside/outside judgment, the input color signal is mapped in the color reproduction range such that a hue angle  $h$  (or  $H$ ) is preserved in the JCH color perception space or QMH color perception space. The  
20 color reproduction range obtained in step S146 is stored in the LUT for the JCH color perception space in a case of relative color matching, or stored in the LUT for the QMH color perception space in a case of absolute color matching.

25 Figs. 10A and 10B are conceptual views of the gamut mapping performed between different devices. In

the drawings, the broken lines indicate a color reproduction range of an input device, and the solid lines indicate a color reproduction range of an output device. In the JCH color perception space, the level of J (lightness) is normalized respectively by illuminant white points under the viewing conditions 1 and 4 (hereinafter referred to as "white point 1" and "white point 4"). Thus, J does not depend on the illuminance level of the viewing condition 1 and luminance level of the viewing condition 4 (hereinafter referred to as "illuminance level 1" and "luminance level 4"). On the other hand, in the QMH color perception space, the level of Q (brightness) changes in accordance with the illuminance level 1 and luminance level 4. Therefore, in the relative color matching, the white point 1 becomes the white point 4. Meanwhile in the absolute color matching, if illuminance level 1 > luminance level 4, the white point 1 is mapped to the white point 4. If illuminance level 1 < luminance level 4, the white point 1 is outputted in gray color because the white point 1 is lower than white point 4.

[Generating Data Dependent on Viewing Condition 4]

Next, the conversion LUT 26 shown in Fig. 13 is generated by the data generation portion 47.

Fig. 15 is a flowchart showing the process of reconstructing the conversion LUT 26 which corresponds to an ambient light.

In the ICC profile for a monitor device, there are cases in which a LUT (BtoA0 Tag or the like) for converting XYZ to device RGB values is stored in the form including information of the gamut mapping. However, since the XYZ values inputted to the LUT employ D50 or D65 as a reference, the XYZ values cannot be directly used as a conversion LUT which corresponds to an ambient light.

As similar to the gamut mapping processing, a conversion matrix (colorant Tag) or a conversion LUT (AtoB0 Tag or the like) for performing RGB-to-XYZ conversion is read from the monitor profile 142 in step S151, and RGB-to-XYZ relation data is obtained from the conversion LUT in step S152. Note that XYZ values of the RGB-to-XYZ relation data may be other device-independent color values, such as Lab values or the like. In step S153, the viewing condition 4 is obtained from the monitor profile 142 which stores the viewing condition 4 in advance.

The XYZ values of the obtained RGB-to-XYZ relation data employ D50 or monitor's white point as a reference. Therefore, the XYZ values of the colorimetric illuminant reference must be corrected to

XYZ values of an ambient light reference in step S154. More specifically, by using the color appearance model, the XYZ values of the colorimetric illuminant reference are converted to the color perception space JCH based  
5 on a colorimetric condition (the white point of D50 illuminant, a luminance level, and the state of ambient light), and then the converted values in the color perception space JCH are converted back to XYZ values based on the viewing condition 4 (the white point of  
10 D93 illuminant, a luminance level, and the state of ambient light) which is different from the colorimetric condition. By this, XYZ values of the colorimetric illuminant reference are converted to XYZ values of the ambient light reference. In the foregoing manner, the  
15 relation between the device RGB values and XYZ values of the ambient light reference is obtained. In step S155, the RGB-to-XYZ conversion is formulated into a model such as a conversion matrix and optimized by repetition or the like, thereby obtaining the  
20 conversion LUT 26 which corresponds to a desired ambient light.

[Executing Color Matching]

Fig. 12 is a conceptual view of color matching  
25 processing. Reference numeral 21 denotes a conversion LUT generated based on the viewing condition 1 by the

data generation portion 41; 132, a LUT generated in the JCH color space by the gamut mapping portion 44; 133, a LUT generated in QMH color space by the gamut mapping portion 45; and 26, a conversion LUT generated based on the viewing condition 4 by the data generation portion 47.

RGB input color signals are converted by the conversion LUT 21 from the input-device-dependent color signals to XYZ signals which are device-independent signals under the viewing condition 1. Next, the XYZ signals are converted by color appearance model forward converters 134 and 135 to perception signals JCH or QMH, based on the viewing condition 1, such as the white point of D50 illuminant, an illuminance level, and the state of ambient light. In a case of relative color matching, JCH space is selected, while in a case of absolute color matching, QMH space is selected.

The color perception signals JCH and QMH are mapped to a color reproduction range of the monitor device by the LUT 132 and 133. The color perception signals JCH and QMH, where the gamut mapping has been performed, are converted by color appearance model inverse converters 136 and 137 to XYZ signals which are device-independent signals under the viewing condition 4, based on the viewing condition 4, such as the white point of D93 illuminant, a luminance level, and the

state of ambient light. Then, XYZ signals are converted to monitor-device-dependent color signals under the viewing condition 4 by the conversion LUT 26.

The RGB signals obtained by the above processing are sent to the monitor device, and an image represented by the color signals is displayed on the monitor device. When the displayed image is viewed under the viewing condition 4, the colors of the displayed image are perceived as the same as the original document viewed under the viewing condition 1.

#### <Third Embodiment>

Hereinafter, described as a third embodiment is an example of color matching utilizing a monitor profile and output profile shown in Fig. 16. Note that the construction and processing similar to that of the first and second embodiments will not be described in detail.

In the ICC profile for a monitor device, a conversion matrix (colorant Tag) or a conversion LUT (AtoB0 Tag) for performing RGB-to-XYZ conversion is stored. In step S162 in Fig. 17, RGB-to-XYZ relation data is obtained. Since the profile includes the viewing condition 4, the viewing condition 4 is obtained from the profile in step S163. Note that XYZ values of the RGB-to-XYZ relation data may be other



device-independent color values such as Lab values.

The XYZ values of the obtained RGB-to-XYZ relation data employ D50 or monitor's white point as a reference. Therefore, the XYZ values of the

5 colorimetric illuminant reference must be corrected to XYZ values of an ambient light reference in step S164. More specifically, by using the color appearance model, the XYZ values of the colorimetric illuminant reference are converted to the color perception space JCH based

10 on a colorimetric condition (the white point of D50 illuminant, a luminance level, and the state of ambient light), and then the converted values in the color perception space JCH are converted back to XYZ values based on the viewing condition 4 (the white point of

15 D93 illuminant, a luminance level, and the state of ambient light), which is different from the colorimetric condition. By this, XYZ values of the colorimetric illuminant reference are converted to XYZ values of the ambient light reference. In the

20 foregoing manner, the relation between the device RGB values and XYZ values of the ambient light reference is obtained. In step S165, the conversion matrix (colorant Tag) or conversion LUT (AtoB0 Tag) in the monitor profile 142 is updated, thereby obtaining a

25 conversion LUT 31 which corresponds to a desired ambient light.

[Selecting Gamut Mapping Mode and Performing Gamut Mapping]

Since the selection of a gamut mapping mode is  
5 performed in the same manner as that of the first  
embodiment, detailed description will not be provided.  
Furthermore, since the gamut mapping is also performed  
in the same manner as that described in the first  
embodiment shown in Fig. 6, detailed description will  
10 not be provided.

[Generating Data Dependent on Viewing Condition 2]

Next, a conversion LUT 36 is generated by the  
data generation portion 47. Since the processing is  
15 the same as that described in the first embodiment  
shown in Fig. 11, detailed description will not be  
provided.

[Executing Color Matching]

20 Fig. 12 is a conceptual view of color matching  
processing. Reference numeral 31 denotes a conversion  
LUT generated based on the viewing condition 4 by the  
data generation portion 41; 132, a LUT generated in the  
JCH color space by the gamut mapping portion 44; 133, a  
25 LUT generated in QMH color space by the gamut mapping  
portion 45; and 36, a conversion LUT generated based on

the viewing condition 2 by the data generation portion 47.

RGB input color signals are converted by the conversion LUT 31 from the monitor-device-dependent color signals to XYZ signals which are device-independent signals under the viewing condition 4. Next, the XYZ signals are converted by color appearance model forward converters 134 and 135 to perception signals JCH or QMH, based on the viewing condition 4, such as the white point of D93 illuminant, a luminance level, and the state of ambient light. In a case of relative color matching, JCH space is selected, while in a case of absolute color matching, QMH space is selected.

The color perception signals JCH and QMH are mapped to a color reproduction range of the output device by the LUT 132 and 133. The color perception signals JCH and QMH, where the gamut mapping has been performed, are converted by color appearance model inverse converters 136 and 137 to XYZ signals which are device-independent signals under the viewing condition 2, based on the viewing condition 2, such as the white point of D65 illuminant, an illumination level, and the state of ambient light. Then, XYZ signals are converted to output-device-dependent color signals under the viewing condition 2 by the conversion LUT 36.

The CMYK signals obtained by the above processing are sent to the output device, and an image represented by the color signals is printed. When the printout is viewed under the viewing condition 2, the colors of the printout are perceived as the same as the image viewed under the viewing condition 4.

<Fourth Embodiment>

In each of the foregoing embodiments,  
10 descriptions have been provided for an example in which a color matching module CMM dynamically converts a profile, which has been generated from a colorimetric value employing D50 and D65 as a reference, into a profile which is dependent on a viewing condition.  
15 Instead, by generating a profile which is fixed to a viewing condition in advance, color matching corresponding to an ambient light can be performed.

Hereinafter described as a fourth embodiment is a method of generating a profile dependent on a viewing  
20 condition for selecting a corresponding profile from a plurality of profiles respectively corresponding to viewing conditions.

[Generating Profile Dependent on Viewing Condition in  
25 Data Source Side]

Data 11 for a conversion LUT, which is dependent

on a viewing condition of the data source side, is generated based on a profile which has been generated from a colorimetric value employing D50 or D65 as a reference, by the processing similar to the processing of the data generation portion 41 shown in Fig. 3 for generating data dependent on the viewing condition of the data source side. Since the data 11 is a conversion matrix or a conversion LUT for converting device RGB (or CMYK) values to XYZ (or Lab) values under a viewing condition of the data source side, the data 11 may be stored in the profile without further processing, thereby forming a profile dependent on the viewing condition of the data source side.

15 [Generating Profile Dependent on Viewing Condition in Data Destination Side]

Data of the LUT 132 and 133 shown in Fig. 12 for performing the gamut mapping process in the JCH and QMH color spaces, which are dependent on a viewing condition of the data destination side, and data 16 for a conversion LUT, which is dependent on a viewing condition of the data destination side, are generated based on the profile which has been generated from a colorimetric value employing D50 or D65 as a reference, by the processing similar to the processing of the gamut mapping portions 44 and 45 and data generation

portion 47 shown in Fig. 3.

Since the input/output color space for the data of the LUT 132 is in the JCH color space, the input color space must be XYZ (or Lab) values which base upon a viewing condition of the data destination side. To generate a conversion LUT for converting XYZ values under the viewing condition of the data destination side to CMYK (RGB) values for a device, CMYK values for the device, which correspond to the input XYZ values under the viewing condition of the data destination side, are obtained. In other words, XYZ values under the viewing condition of the data destination side are converted to color perception values JCH under the viewing condition of the data destination side by the color appearance model forward conversion, then compressed in the JCH color space by the data of the LUT 132. Then, the color perception values JCH are converted back to XYZ values under the viewing condition of the data destination side by the color appearance model inverse conversion, and conversion based on the data of the LUT 134 is performed. By this, CMYK values for a desired device are obtained. A conversion LUT can be generated by sequentially obtaining LUT grid points.

Similarly, since the input/output color space for the data of the LUT 133 is in the QMH color space, the

input color space must be XYZ values which base upon a viewing condition of the data destination side. To generate a conversion LUT for converting XYZ values under the viewing condition of the data destination side to CMYK values for a device, CMYK values for the device, which correspond to the input XYZ values under the viewing condition of the data destination side, are obtained. In other words, XYZ values under the viewing condition of the data destination side are converted to color perception values QMH under the viewing condition of the data destination side by the color appearance model forward conversion, then compressed in the QMH color space by the data of the LUT 133. Then, the color perception values QMH are converted back to XYZ values under the viewing condition of the data destination side by the color appearance model inverse conversion, and conversion based on the data of the LUT 134 is performed. By this, CMYK values for a desired device are obtained. A conversion LUT can be generated by sequentially obtaining LUT grid points.

The LUT 132 is used in relative color matching, while the LUT 133 is used in absolute color matching. By storing these LUTs in a single profile, a profile which is dependent on the viewing condition of the data destination side can be generated. Herein, a plurality of LUTs for relative color matching can be produced and

stored by the gamut mapping method (lightness preservation, chroma preservation or the like) in the JCH color space. Similarly, a plurality of LUTs for absolute color matching can be produced and stored by  
5 the gamut mapping method (brightness preservation, colorfulness preservation or the like) in the QMH color space.

[Executing Color Matching]

10 In the color matching using a profile dependent on a viewing condition, the gamut mapping process is included in the profile in the data destination side. Therefore, the gamut mapping in JCH color space or QMH color space does not need to be performed as described  
15 in each of the foregoing embodiments.

Color matching using a profile dependent on a viewing condition is described with reference to Figs. 2, 13 and 16.

Input color signals are converted from device-  
20 dependent RGB (or CMYK) values to XYZ (or Lab) values under the viewing condition of the data source side, by the profile dependent on the viewing condition of the data source side.

Next, XYZ values under the viewing condition of  
25 the data source side are converted to JCH color space or QMH color space by the color appearance model



forward conversion, and then converted back to XYZ values under the viewing condition of the data destination side by the color appearance model inverse conversion. Herein, selection of the JCH or QMH color space is determined by the gamut mapping mode. In a case of relative color matching, JCH color space is selected, while in a case of absolute color matching, QMH color space is selected. Furthermore, the conversion from XYZ values to JCH or QMH color space applies the viewing condition of the data source side, such as the white point of an illuminant, an illuminance level or luminance level, and the state of ambient light, stored in the profile in the data source side. In the inverse conversion, the viewing condition of the data destination side, such as the white point of an illuminant, an illuminance level or luminance level, and the state of ambient light, stored in the profile in the data source side, is employed. The converted XYZ (or Lab) values under the viewing condition of the data destination side are converted to the device CMYK (or RGB) values by the profile dependent on the viewing condition of the data destination side.

As has been described above, the color matching processing using a profile dependent on a viewing condition according to the fourth embodiment is

equivalent to the color matching processing in the first to third embodiments.

<Fifth Embodiment>

- 5           In each of the foregoing embodiments, a profile dependent on a viewing condition is generated from one type of colorimetric value stored in advance in a profile. However, in order to improve matching precision, it is better that colorimetric data for plural illuminants are stored in the profile, then colorimetric data which is closest to the actual viewing condition is selected from the plural colorimetric data and converted to colorimetric data corresponding to the actual viewing condition, and a profile dependent on the viewing condition is generated.
- 10
- 15

Fig. 20 is a conceptual view of a profile 191 storing XYZ values of a white point under different illuminants, device-dependent RGB values of a color target, and XYZ values corresponding to the color target under respective illuminants.

20

The color target serves as, for instance, a color target of IT8 defined by ANSI in a case of an input device, and serves as, for instance, 9x9x9 RGB color patches in a case of an output device. For instance, reference numeral 192 denotes RGB values of a color target and XYZ values under illuminant A (109.85, 100.0,

25

35.58); 193, RGB values of a color target and XYZ  
values under illuminant D65 (95.05, 100.0, 108.88); 194,  
RGB values of a color target and XYZ values under  
illuminant D50 (96.42, 100.0, 82.49); and 195, RGB  
5 values of a color target and XYZ values under  
illuminant F2 (99.20, 100.0, 67.40). XYZ values of a  
color target under different illuminants as mentioned  
above can be obtained from a spectral distribution of  
each illuminant and a spectral reflectance of each  
10 color target. Therefore, instead of each of the XYZ  
values, the spectral distribution of each illuminant  
and spectral reflectance of each color target may be  
stored in the profile 191. Herein, if the color target  
used in each profile is fixed, RGB values of each color  
15 target and data for spectral reflectance are common for  
each illuminant. Therefore, data related to the color  
target can be shared in each of the illuminants.

Fig. 21 shows a spectral distribution of a  
standard illuminant, wherein reference numeral 201  
20 denotes a spectral distribution for the illuminant A,  
and reference numeral 202 denotes a spectral  
distribution for illuminant D65. By measuring a  
spectral distribution of an illuminant in an actual  
viewing condition, it is possible to generate a profile  
25 dependent on a viewing condition with better precision.

As shown in Fig. 20, in a case where XYZ values

under a plurality of standard illuminants, such as the illuminants A, D65, D50, and F2, are stored in the profile, XYZ values under a standard illuminant which is closest to the actual viewing condition are

5 converted to XYZ values for the viewing condition. To select the XYZ values under an illuminant closest to the viewing condition, a search is performed utilizing the XYZ values of a white point under illuminants, which have been stored in the profile. For instance,  
10 assuming that the white point under each illuminant is  $X_w Y_w Z_w$ , the chromaticity ( $x_w$ ,  $y_w$ ) can be obtained by equation (7).

$$\left. \begin{aligned} x_w &= \frac{X_w}{X_w + Y_w + Z_w} \\ y_w &= \frac{Y_w}{X_w + Y_w + Z_w} \end{aligned} \right\} \quad \dots(7)$$

15

Similarly, the chromaticity ( $x$ ,  $y$ ) of the white point under the viewing condition is obtained by equation (8). A distance  $d_w$  from a white point under each illuminant to a white point under a viewing  
20 condition is evaluated by, for instance, equation (9).

70540

$$\left. \begin{aligned} x &= \frac{X}{X+Y+Z} \\ y &= \frac{Y}{X+Y+Z} \end{aligned} \right\} \quad \dots(8)$$

$$dw = \sqrt{(x - xw)^2 + (y - yw)^2} \quad \dots(9)$$

5 From the above calculation result, colorimetric data which is closest to the actual viewing condition is selected, thereby obtaining XYZ values which base upon the viewing condition, with better precision. Herein, the method similar to the above-described

10 embodiments is used to convert XYZ values stored in the profile to XYZ values which base upon a viewing condition. The XYZ values of the colorimetric illuminant reference are converted to the color perception space JCH by the color appearance model

15 based on a colorimetric condition, and then converted back to XYZ values based on a viewing condition different from the colorimetric condition. In a case where the distance  $dw$  from a white point under each illuminant to a white point under the viewing condition

20 is zero, the colorimetric data may be used as the XYZ values for the viewing condition. Besides this, the distance may be evaluated by a difference between a color temperature  $T_w$  of a white point under each

illuminant and a color temperature  $T$  of a white point under a viewing condition.

Fig. 22 is a flowchart showing the process of conjecturing a colorimetric value from the colorimetric data for plural illuminants. Herein, step S211 in Fig. 22 corresponds to step S44 in Fig. 4, step S54 in Fig. 5, step S64 in Fig. 6, step S74 in Fig. 7, step S144 in Fig. 14, step S154 in Fig. 15, and step S174 in Fig. 17.

#### 10 [Caching Profile Data Dependent on Viewing Condition]

As mentioned above, because the processing for generating a profile dependent on a viewing condition is relatively complicated, it is time consuming to perform calculation each time color matching or the like is executed. In the normal usage state, once the viewing conditions of the data source side and the data destination side are set, it is often the case that users do not change the setting. Therefore, by caching a LUT or the like for mutually converting a device-independent color space to a device-dependent color space under a viewing condition, it is possible to improve the processing efficiency.

Since the viewing condition can be set independently for the data source side and data destination side, the LUT for mutually converting a device-independent color space to a device-dependent

color space under a viewing condition is cached for each profile. The LUT is cached in each profile or other cache files. A LUT corresponding to the current viewing condition may be cached, or a LUT corresponding to plural viewing conditions may be cached in unit of each viewing condition.

For instance, in a case of using ICC profile, a LUT for a viewing condition, which corresponds to AtoBx Tag, BtoAx Tag, Gamut Tag or the like in each profile, is stored as a private tag.

Fig. 23 shows an example in which a LUT, provided for mutually converting a device-independent color space which bases upon a viewing condition to a device-dependent color space, is stored in the ICC profile.

In the profile 221 including the cached LUT, AtoB0 Tag 222, AtoB1 Tag 223, AtoB2 Tag 224, BtoA0 Tag 225, BtoA1 Tag 226, BtoA2 Tag 227, and gamut Tag 228 are stored as a public tag. Herein, the LUT stored as a public tag is provided for mutually converting a device-independent color space employing D50 reference to a device-dependent color space. Furthermore, the profile 228 includes, as a private tag, LUTs 229 to 2215 which correspond to public tags 222 to 227, for mutually converting a device-independent color space which bases upon a viewing condition to a device-dependent color space. In the private tag, a viewing condition 2216 at

the time of caching is stored independently of the  
cached LUT.

Fig. 24 is a flowchart showing caching processing.  
The processing described hereinafter is an independent  
5 process for the data source side and for the data  
destination side.

First, a viewing condition VC is obtained by user  
setting or the like. Next, cached LUT's viewing  
condition VC0 is obtained from a profile 232. The  
10 viewing condition VC is compared with the viewing  
condition VC0 in terms of, for instance, a white point  
of an illuminant. If a match is found between the  
viewing conditions, it is determined that the viewing  
condition is the same as the condition where the last  
15 time an LUT is cached. Thus, the cached LUT is used  
for color matching or the like. On the other hand, if  
a match is not found between the viewing conditions, a  
LUT necessary for color matching is generated based on  
the viewing condition.

20 The method of generating a LUT which is dependent  
on a viewing condition is the same as the method  
described with reference to Figs. 4, 6, 7, 12 and 13.  
For the data source side, the conversion LUT 11 shown  
in Fig. 12 is cached, while for the data destination  
25 side, a LUT combining the LUT 132 and conversion LUT 16  
shown in Fig. 12 is cached (i.e., equivalent to the



conversion LUT 21 or 26 shown in Fig. 13). The viewing condition at the time of LUT generation and the LUT which is dependent on the viewing condition are used for color matching or the like, and then stored as a private tag in the profile.

According to each of the above-described embodiments, the following effects are achieved.

(1) Different viewing conditions (white point of an ambient light, illumination level and so on) can be set for each of the image data source side and the image data destination side. By this, for instance, color reproduction under an environment of a remote place connected by a network can be simulated.

(2) XYZ values employing an ambient light in the image data source side as a reference are converted by a human color appearance model to the JCH color space or QMH color space based on a viewing condition of the image data source side (white point of an ambient light, illumination level and so on), and then converted back to XYZ values employing an ambient light in the image data destination side as a reference, based on a viewing condition of the image data destination side (white point of an ambient light, illumination level and so on). By this, color matching can be performed with independent setting of viewing conditions of the image data source side and image data

destination side.

(3) Gamut mapping is performed in the QMH (or JCH) color space, which is the human color perception space. By virtue of this, human color perception characteristics, such as the contour lines of hue, can be reflected upon the gamut mapping, and color matching most appropriate for the ambient light can be performed.

(4) Color matching can be selected from two modes: absolute color matching where the gamut mapping is performed in QMH color space, and relative color matching where the gamut mapping is performed in JCH color space. By virtue of this, it is possible to attempt color matching which is as absolute as possible in the color reproduction range of the output device, or attempt relative color matching which takes the best advantage of the dynamic range of the color reproduction range of the output device, thereby performing color matching most appropriate for the color reproduction range of the output device.

(5) Colorimetric values (XYZ or Lab values) of a color target or color patch are converted to values in the JCH color space by a human color appearance model based on a colorimetric condition (white point of a colorimetric illuminant or illumination level and so on), and then converted back to XYZ (or Lab) values based on a viewing condition (white point of an ambient

light and illumination level and so on). By this, XYZ values employing the colorimetric illuminant as a reference are converted to XYZ values employing an ambient light as a reference.

- 5           (6)    Data indicative of a relation between device-independent data, obtained by colorimetry of a color target under a standard illuminant, and device-dependent data, which is dependent on a device into which the color target data is inputted, is stored in
- 10   an input profile. In accordance with a viewing condition (white point of an ambient light, illumination level and so on) at the time of viewing an image to be inputted, a conversion matrix or a
- 15   conversion LUT for converting device-dependent data to device-independent data is dynamically generated. By this, color matching corresponding to the ambient light at the time of viewing the image to be inputted can be performed. Furthermore, the conversion matrix or
- 20   conversion LUT for converting device-dependent data stored in the input profile to device-independent data (standard illuminant reference) is dynamically updated in accordance with a viewing condition at the time of viewing the image to be inputted (white point of an ambient light, illumination level and so on). By this,
- 25   color matching corresponding to the ambient light at the time of viewing the image to be inputted can be

performed.

(7) A conversion matrix or a conversion LUT for converting device-dependent data stored in a monitor profile to device-independent data (white point reference of a monitor or standard illuminant reference) is dynamically updated in accordance with a viewing condition of a monitor (white point of an ambient light, luminance level and so on). By this, color matching corresponding to an ambient light of a monitor can be performed.

(8) Data indicative of a relation between device-dependent data of a color patch and device-independent data obtained by colorimetry of a printout of the color patch under a standard illuminant, is stored in an output profile. In accordance with a viewing condition (white point of an ambient light, illumination level and so on) at the time of viewing the printout, a conversion LUT for converting device-independent data to device-dependent data is dynamically generated. By this, color matching corresponding to an ambient light at the time of viewing an output original can be performed.

#### <Sixth Embodiment>

Described in a sixth embodiment is an example of a Graphic User Interface (GUI) for manually setting a

viewing condition (e.g., viewing condition 1 or 2 in Fig. 2) for each of the foregoing embodiments.

Fig. 25 shows a GUI 191 for setting a parameter of a viewing condition according to the sixth  
5 embodiment.

Reference numeral 192 denotes a text box for inputting a luminance of a viewing subject at the time of viewing an input; 193, a drop-down combo-box for selecting the type of white point in the viewing  
10 subject at the time of viewing an input; 194, a drop-down combo-box for selecting a viewing condition at the time of viewing an input; 195, a text box for inputting a chromatic adaptability at the time of viewing an input; 196, a text box for inputting a luminance of a  
15 viewing subject at the time of viewing an output; 197, a drop-down combo-box for selecting a white point in the viewing subject at the time of viewing an output; 198, a drop-down combo-box for selecting a viewing condition at the time of viewing an output; and 199, a  
20 text box for inputting a chromatic adaptability at the time of viewing an output.

Note that the luminance relates to the luminance  $L_A$  in the CIE CAM97s shown in Fig. 19; an illuminant relates to  $XwYwZw$ ; an ambient light relates to the  
25 constant  $c$ , factor  $N_c$ , lightness contrast factor  $FLL$  and factor for degree of adaptation  $F$ ; and an

adaptability relates to the variable D. Although the variable D is obtained by LA and F according to the CIE CAM97s in Fig. 19, the variable D according to the sixth embodiment is controlled manually.

- 5 Normally, about 20% of a white point is inputted as a luminance of a viewing subject. To obtain the type of white point in the viewing subject, XYZ values of a white point in the viewing subject are necessary. However, for a simple explanation, it is assumed herein
- 10 that the reflectivity of a white point in the medium used is 100%, and therefore, a white point of an illuminant is used herein. Furthermore, although it is better to utilize a white point of the illuminant under the actual viewing condition, it is assumed herein that
- 15 a standard illuminant type is selected. As the type of standard illuminant, there are illuminants A, C, D65, D50, D93, F2, F8, and F11. Since an image is the viewing subject herein, a relative luminance of the background is assumed to be 20%. With respect to the
- 20 viewing condition, if a relative luminance of the ambient is equal to or larger than 20%, which has been assumed as the background relative luminance, the subject is determined as "average surround". If the ambient relative luminance is less than 20%, the
- 25 subject is determined as "dim". If the ambient relative luminance is almost 0%, the subject is

determined as "dark". With respect to the chromatic adaptability, the value is adjusted such that 1.0 attains complete adaptation and 0.0 attains no adaptation.

5

<Seventh Embodiment>

For setting a parameter of a viewing condition as described in the sixth embodiment, values must be directly inputted. Therefore, handling the GUI is  
10 extremely difficult for general users who are not an color expert. In the seventh embodiment, the GUI 191 described in the sixth embodiment is improved for the ease of use.

The characteristic configuration of the seventh  
15 embodiment is as follows.

(1) Parameter setting display is changed according to a user's level.

(2) A user can adjust the chromatic adaptability by designating a space between a viewing  
20 subject of a data source side and a viewing subject of a data destination side.

(3) A user can adjust the balance of the chromatic adaptability between the viewing subject of a data source side and a viewing subject of a data  
25 destination side.

(4) A user can adjust an absolute chromatic

adaptability while maintaining the balance of the chromatic adaptability between the viewing subject of a data source side and a viewing subject of a data destination side.

5            Fig. 26 shows a GUI 201 which enables setting of a user level. Fig. 26 shows the state in which "general user" is set as a user level. In the GUI 201, a user does not need to directly input a parameter, but is able to set all the viewing conditions by making  
10 selection or adjusting a slide bar. The contents of selections are expressed in a user-friendly manner.

Referring to Fig. 26, reference numeral 202 denotes a drop-down combo-box for selecting a user level; 203, a drop-down combo-box for selecting a  
15 viewing subject at the time of viewing an input; 204, a drop-down combo-box for selecting a luminance level in the viewing subject at the time of viewing the input; 205, a drop-down combo-box for selecting the type of white point in the viewing subject at the time of  
20 viewing the input; 206, a drop-down combo-box for selecting a viewing condition at the time of viewing the input; 207, a drop-down combo-box for selecting a viewing subject at the time of viewing an output; 208, a drop-down combo-box for selecting a luminance level  
25 in the viewing subject at the time of viewing the output; 209, a drop-down combo-box for selecting the



type of white point in the viewing subject at the time  
of viewing the output; 2010, a drop-down combo-box for  
selecting a viewing condition at the time of viewing  
the output; 2011, an icon indicative of the viewing  
5 subject at the time of viewing an input with the set  
viewing spacing; and 2012, an icon indicative of the  
viewing subject at the time of viewing an output with  
the set viewing spacing.

The displayed user level is switched, for  
10 instance, as shown in Fig. 27, by designating the drop-  
down combo-box 202 for selecting a user level. Items  
of selectable viewing subject include "monitor",  
"original document", "printout" and so forth, and  
depending on the selected item, items of selection menu  
15 and values set according to the item vary. Items of  
selectable luminance level for the viewing subject  
include "bright", "relatively light", "average",  
"relatively dark", which are expressed in the intuitive  
manner for general users. Also, items of selectable  
20 white point in the viewing subject do not include  
expressions for expert users such as D93 or F2 or the  
like, but include expressions for general users, such  
as "bluish white", "white", and "yellowish white" for a  
monitor, and "white fluorescent light", "neutral white  
25 fluorescent light", "incandescent light", "clear  
weather in the open air", "overcast weather in the open

air" for an original document or printout.

For setting a viewing space, the space between the viewing subjects is adjusted by operating the slide bar, for instance, for comparing a monitor and a printout placed next to each other, or comparing the subjects placed apart from each other. The setting concerns with determination of a chromatic adaptability. The viewing subjects are expressed by icons so that a user can intuitively adjust the distance between the icons by using a slide bar.

The chromatic adaptability is defined by the following equation according to CIE CAM97s.

complete adaptation :  $D = 1.0$

no adaptation :  $D = 0.0$

incomplete adaptation :  $D = F - \frac{F}{1 + 2 LA^{\frac{1}{3}} + \frac{LA^2}{300}}$

Herein, D indicates the chromatic adaptability. F indicates a constant which varies in accordance with a viewing condition, wherein F is 1.0 in the average surround and 0.9 in the dim or dark condition. La indicates a luminance in the viewing subject. The chromatic adaptability D can be set independently for the input side and output side.

In the present embodiment, the chromatic

adaptability at the time of viewing an input and output is defined such that the chromatic adaptability is changed in accordance with the space (viewing distance) between the viewing subject in the input side and the viewing subject in the output side. Assuming that the complete adaptation is most closely achieved when the viewing distance is infinite, the chromatic adaptability can be defined by the following equation.

10

$$Ds0 = Fs - \frac{Fs}{1 + 2 \cdot LAs^{\frac{1}{4}} + \frac{LAs^2}{300}}$$

$$Dd0 = Fd - \frac{Fd}{1 + 2 \cdot LAd^{\frac{1}{4}} + \frac{LAd^2}{300}}$$

$$Ds = Ds0 \cdot VD + Ds0 \cdot VD0 \cdot (1.0 - VD)$$

$$Dd = Dd0 \cdot VD + Dd0 \cdot VD0 \cdot (1.0 - VD)$$

Herein, Ds0 indicates a chromatic adaptability at the time of viewing an input, which is determined by the luminance level and viewing condition. Fs indicates a constant which varies in accordance with the viewing condition at the time of viewing the input. LAs indicates a luminance in a viewing subject at the time of viewing the input. Dd0 indicates a chromatic adaptability at the time of viewing an output, which is determined by the luminance level and viewing condition. Fd indicates a constant which varies in accordance with

the viewing condition at the time of viewing the output.  
LAd indicates a luminance in a viewing subject at the  
time of viewing the output. Ds indicates a chromatic  
adaptability at the time of viewing an input, which is  
5 determined by the viewing distance, luminance level,  
and viewing condition. Dd indicates a chromatic  
adaptability at the time of viewing an output, which is  
determined by the viewing distance, luminance level,  
and viewing condition. VD indicates the position of a  
10 slide bar indicative of a viewing distance, wherein if  
the viewing distance is zero, VD takes the minimum  
value 0.0, while if the viewing distance is infinity,  
VD takes the maximum value 1.0. VD0 indicates a  
constant for determining a chromatic adaptability when  
15 the viewing distance is zero.

Fig. 27 shows a GUI 211 in a case where the user  
level is set in the "professional" level. Since the  
GUI is for expert users, parameters can be inputted  
directly, and items are expressed by technical  
20 expressions.

Herein, reference numeral 2111 denotes a static  
text for displaying a value of a chromatic adaptability  
as a viewing condition at the time of viewing an input;  
2112, a static text for displaying a value of a  
25 chromatic adaptability as a viewing condition at the  
time of viewing an output; 2113, a slide bar for

adjusting the balance of a chromatic adaptability  
between a viewing subject in the input side and a  
viewing subject in the output side; and 2114, a slide  
bar for adjusting an absolute chromatic adaptability  
5 while maintaining the balance of the chromatic  
adaptability between the viewing subject in the input  
side and the viewing subject in the output side.

The chromatic adaptability in the input side and  
output side is defined as follows so as to be  
10 adjustable by the balance and absolute intensity.

$$Ds0 = 1.0 - BL$$

$$Dd0 = BL$$

$$Ds = \frac{Ds0}{MAX(Ds0, Dd0)} \times VL$$

$$Dd = \frac{Dd0}{MAX(Ds0, Dd0)} \times VL$$

Herein, Ds0 indicates a chromatic adaptability at  
15 the time of viewing an input, which is determined by  
the balance adjustment of the chromatic adaptability.  
Dd0 indicates a chromatic adaptability at the time of  
viewing an output, which is determined by the balance  
adjustment of the chromatic adaptability. BL indicates  
20 the position of a slide bar indicative of a balance,  
wherein if the balance at the time of viewing an input

is 100%, BL takes the minimum value 0.0, and if the balance at the time of viewing an output is 100%, BL takes the maximum value 1.0, and the center is 0.5. Ds indicates a chromatic adaptability at the time of viewing an input, which is determined by the balance of the chromatic adaptability and absolute intensity adjustment. Dd indicates a chromatic adaptability at the time of viewing an output, which is determined by the balance of the chromatic adaptability and absolute intensity adjustment. VL indicates the position of a slide bar indicative of an absolute intensity, wherein if the intensity is zero, VL takes the minimum value 0.0, and if the intensity is maximum, VL takes the maximum value 1.0. Note that MAX() indicates the selection of the maximum value in the parenthesis.

The balance is adjusted such that the complete adaptation is attained when the balance intensity is large. Then, the balance intensity adjusts the entire chromatic adaptability while maintaining the balance. In other words, if the balance is set in the center and the absolute intensity is set to the maximum value, the chromatic adaptability in the input side and output side both attains complete adaptation.

The present invention can be applied to a system constituted by a plurality of devices (e.g., host

computer, interface, reader, printer) or to an apparatus comprising a single device (e.g., copying machine, facsimile machine).

Further, the object of the present invention can  
5 also be achieved by providing a storage medium storing program codes for performing the aforesaid processes to a computer system or apparatus (e.g., a personal computer), reading the program codes, by a CPU or MPU of the computer system or apparatus, from the storage  
10 medium, then executing the program.

In this case, the program codes read from the storage medium realize the functions according to the embodiments, and the storage medium storing the program codes constitutes the invention.

15 Further, the storage medium, such as a floppy disk, a hard disk, an optical disk, a magneto-optical disk, CD-ROM, CD-R, a magnetic tape, a non-volatile type memory card, and ROM can be used for providing the program codes.

20 Furthermore, besides aforesaid functions according to the above embodiments are realized by executing the program codes which are read by a computer, the present invention includes a case where an OS (operating system) or the like working on the  
25 computer performs a part or the entire processes in

accordance with designations of the program codes and realizes functions according to the above embodiments.

Furthermore, the present invention also includes a case where, after the program codes read from the  
5 storage medium are written in a function expansion card which is inserted into the computer or in a memory provided in a function expansion unit which is connected to the computer, CPU or the like contained in the function expansion card or unit performs a part or  
10 the entire process in accordance with designations of the program codes and realizes functions of the above embodiments.

The present invention is not limited to the above embodiments and various changes and modifications can  
15 be made within the spirit and scope of the present invention. Therefore, to appraise the public of the scope of the present invention, the following claims are made.